differ considerably among themselves as to the quality of water they may select for their abode; *Notonecta undulata,* for instance, may occur in the foulest kind of pools, while others must have comparatively clean water.

The family Naucoridæ includes some broad, ovate forms which seem to prefer waters well stocked with vegetable matter. They have the usual talon-like fore legs, but as their hind legs are neither broadened nor fringed with hair, they are poor swimmers, depending more upon walking about upon the submerged plants.

Of all of the Heteroptera perhaps the aquatic species have been less well and accurately known to American entomologists than any other group. This has been due to the fact that because of their wide distribution, ease of collecting, and generally larger size they received the attention of earlier systematists, who were satisfied to give them but a brief and not distinctive characterization to make them recognizable without an examination of the types. These types, for the most part, having either been destroyed or deposited in museums abroad systematists have depended upon the meager descriptions at hand, with the result that there has arisen considerable confusion and uncertainty in fixing certain species. Especially is this so in the family Corixidæ.

AQUATIC COLEOPTERA.

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Few, if any, beetles are aquatic throughout all the stages of their existence; even those commonly called water beetles pupate on land and sometimes at least lay their eggs on leaves out of the water. The beetles which are more or less aquatic in habit include the several families of water beetles, the Parnidæ and Elmidæ, the tribe Donaciini in Chrysomelidæ, some tribes of snout beetles and a few other smaller families. All of these exhibit some modifications of structure and vestiture in harmony with their aquatic life, modifications that are on the whole more marked in the adults than in the larvæ, especially in the case of the plant-infesting species; all exhibit a more

or less definite preference for certain environments by which their distribution is governed, while at the same time this distribution is also more or less controlled by such factors as temperature and accident.

The modifications involve the parts used in locomotion and for attachment to stationary objects, in copulation, in flotation and particularly in respiration. The modifications of the legs of the Dytiscidæ to fit them for swimming and of the male front tarsi to assist in holding the female are too well known to need extended mention. The great development of the claws in Parnidæ and Elmidæ, which, living often in rapid streams, require these elongated and recurved appendages to maintain their position, is probably also sufficiently well known. The modification of the claws of Haliplidæ larvæ to enable them to maintain their position on filamentous algæ is not so well known. It is well described by Matheson in the September number of our JOURNAL. In the study of the modifications of vestiture of aquatic insects and their relation to flotation and respiration, such progress has been made by Frank Brocher during the last three years, that a more detailed mention is necessary, particularly as, according to his conclusions, much of the information contained in our books is erroneous.

The surface of the body of aquatic insects is often observed to be covered at least in part with hair, or in some snout beetles by closely imbricated scales instead, both evidently designed to keep the body dry so that the hairs have received the name of hydrofuge pubescence. Such insects in the water are often observed with a silvery globule of air entangled in the pubescence. Moreover, special appliances for retaining air are found, as in the enlarged coxal plates of the Haliplidæ, and in the arched elytra of the Hydrophilidæ, leaving a relatively great space between them and the dorsal aspect of the abdomen, in which the stigmata are situated. The Dytiscidæ may be seen coming to the surface and hurriedly descending with a globule of air attached to the anal extremity. All these facts seem to point to the conclusion that such insects are thus provided with hairs, etc., to enable them to carry air with them below the surface of the water for breathing purposes. But quite erroneously, if as Brocher has sought to demonstrate such supplies of air are more nearly analogous to that contained in the sound of a fish, and serve the purpose of lessening

the specific gravity of the creature, and thus assisting it in floating. The body of a whirligig is hairy beneath; the air entangled in the hairs in part supports the beetle on the surface, and permits of its evolutions. A muscular effort is necessary to send many water beetles below the surface, and their claws are required to keep them below, grasping some water plant. This is illustrated in the floating to the surface of *Hydrochus* and *Helophorus,* when the water net disturbs their grip on aquatic plants. With others, as the Dytiscidæ, the escape of the air from beneath the elytra increases their specific gravity and their descent is thereby facilitated. The bubble of air seen at the anal extremity as a Dytiscid disappears beneath the water is an expelled bubble, not one that is to be inhaled. In short, the phenomena and structural modifications heretofore assumed to be connected with respiration are, at least in great part, connected with flotation or maintenance of equilibrium.

Respiration is according to Brocher effected in Haliplidæ and Dytiscidæ by drawing in air through the last two abdominal stigmata, and expelling it through the other stigmata, particularly the anterior pair. He has detected in *Cybister* and less distinctly in other genera air pockets in the midst of the muscular masses of the meso-thorax and meta-thorax, which are connected directly with these anterior stigmata, and explain their larger size, but he expresses an opinion that no large quantity of air is habitually stored therein, the action of respiration being in these beetles rather a thorough ventilation of the whole tracheal system. The arrangement of the stigmata and their relation to the extraordinarily enlarged coxal plates is illustrated in the September number of our JOURNAL. In other aquatic insects, and especially those which do not come to the surface frequently to breathe, but remain below the surface for long periods, even for weeks at a time in some cases, a complicated system of pubescence serves to supply the small quantity of air required by comparatively inactive creatures, and to permit of this supply being obtained from aquatic plants or from the aerated waters of rapid streams. The simple hydrofuge pubescence, consisting of hairs set nearly perpendicular to the body and designed simply to retain a body of air, is replaced by a double arrangement of hairs; one series is curved so as to become parallel to the body and applied one above the other, like shingles, whereby a sheath-like enclosure of the body is effected, and a second

series external to the first and capable of absorbing and holding the aerated water from which an attenuated layer of air is supplied to the space enclosed by the first series of curved hairs. Such hairs are found in Elmidæ, in *Hæmonia,* and in all the snout beetles like *Tanysphyrus* that live on aquatic plants and live habitually beneath the surface of the water. Experimentally Brocher found Elmidæ capable of maintaining life for at least eight weeks in aerated water, but dying soon in water deprived of air. *Hæmonia* was found to live about three weeks deprived of air and indefinitely when kept submerged but in communication with aquatic plants. Such beetles must therefore be regarded as even more completely aquatic than those commonly called water beetles.

The interesting observations of Brocher are barely sketched in these remarks, details of the respiration of many different aquatic insects may be found in his papers published in the Annales de Biologie Lacustre, Vols. 4 and 5, 1909 to 1911, with copious illustration and with the strongest internal evidence of conscientious work.

EARLY STAGES.

Special emphasis has so far been laid upon the imago stage. The importance of the larval stage in which presumably the creatures pass the greater part of their lives, feeding, growing and actively performing all their functions except reproduction, must be admitted; but unfortunately little beyond the most general information is available, for since the days of Schaupp few hereabouts except Joutel have taken any interest in rearing Coleoptera. The work thus far done on American species has been indexed by Beutenmuller, but the work of European authors is our main reliance and from it in part the following remarks have been compiled:

The larvæ of Haliplidæ, Dytiscidæ, Hydrophilidæ, Gyrinidæ and Parnidæ are purely aquatic, living wholly in the water, but not swimming. The eggs are frequently laid upon plants out of the water, sometimes within a silken enclosure, that of the Hydrophilidæ being provided with a curious prolongation as if the quantity of silk had been excessive and twisted into a pointed appendage. The larvæ of Parnidæ and Elmidæ are attached to stones, etc., by lateral expansions of the segments, and in the case of *Dryops* and *Psephenus* become almost circular in outline, and so nearly resemble Crustacea that

Psephenus larva was in fact described by DeKay as a Crustacean. The larvæ of the other families crawl along the bottom or on stems of aquatic plants, feeding on animal food in the Dytiscidæ, vegetable or mixed food in the other families, filamentous algæ in the Haliplidæ according to Matheson. The breathing apparatus is modified in these larvæ, usually tracheal extensions from the apex of the body, permitting of the creature's drawing a supply of atmospheric air by resting head down at the surface with these appendages protruding above the surface. In the larvæ of Gyrinidæ such appendages proceed from all the segments except those bearing legs, so that the larva has somewhat the appearance of a centipede. In the larvæ of some Haliplidæ, the air supply, according to Matheson, is obtained by means of numerous long-jointed tracheated spines. The larvæ of *Cnemidotus* are illustrated by Schiodte with two long slender lateral filaments proceeding from each segment, and with four recurved hooks on the anal segment, which would assist the larvæ in maintaining its hold on plants. The larvæ of *Psephenus* have been described in detail by Kellicott, in the Canadian Entomologist. They are almost circular and have waving extensions from the different segments. Among the Elmidæ, the larvæ of some species live in the exceedingly soft mud of the banks of streams and have been studied by Dufour and other foreign authors. In the larvæ of *Donacia* the eighth segment is provided with two spines apparently used for piercing the air cells of aquatic plants.

In general the larvæ of aquatic beetles may be said to be modified in respect of respiratory apparatus but otherwise they greatly resemble terrestrial larvæ.

ENVIRONMENT.

The interesting fact in connection with such aquatic Coleoptera is that each requires more or less absolutely a special environment for its development. In the cases in which it is insistent upon a particular environment, it becomes rather rare from the scarcity of the conditions it craves. Among the Dytiscidæ, for example, we find *Agabetes acuductus* only in small woodland pools, with many fallen decaying leaves. In the water itself of such pools this species is likely to be missing, but crawling among the submerged rotting leaves near the edge of the pond they may be found, probably hunting some

little animals that feed upon leaves; so also with *Copelatus glyphicus* which I have found only in submerged rotting cattails, between the layers of which their greatly flattened bodies permit them to crawl. Such species might be called rare, it is really only necessary to find their environment to find them in sufficient numbers. On the other hand, a genus like *Ilybius* seems to turn up in a variety of situations. As one recalls the days spent with the water net, how it comes to mind that Linell told us the larger species preferred the deeper waters, and must be hunted by wading bare-legged into the pond, a method that Mr. Roberts' hip boots, carried in a neat suitcase, seemed to indorse but improve. How one thinks longingly of the day *Canthydrus puncticollis* was fished out of a tiny spring hole on Staten Island, but only one specimen not since repeated; and of another day when dragging the net along the grassy edge of a little brook, produced a few *Deronectes depressus*. Along the edge of the Staten Island salt meadow, I have found *Cœlambus impressopunctatus* with scarcely enough water to keep them as wet as were my feet. It may be that some of the associations of environment and species are deceiving on account of the facility with which at least some species fly by night, especially during their mating season, and of the lack of discrimination they display in alighting. I have heard of their mistaking greenhouse glass for water, and if capable of so serious an error, they might easily get mixed as to their appropriate environments, therefore too much importance must not be attached to records of the finding of a few imagos. Nevertheless it is evident that for most species of water beetles a particular environment is an absolutely essential requisite for successful search.

The Hydrophilidæ are generally regarded as vegetable feeders, though Folsom says the larvæ are at time carnivorous, and Miss Bamford found them in captivity practically omnivorous. As now classified in our books we have three sub-families of vastly different habits combined under the name, namely: *Cercyon* and its allies, found in manure and in no sense aquatic, the Helophorini found on plants beneath the surface, crawling on them and incapable of swimming, resembling rather the Elmidæ in their habits, and the true *Hydrophilus* and its allies, all more or less free swimming creatures though none of them can equal the Dytiscidæ in this respect. As would naturally follow from their habits, these feeders upon vegetable

matter are seldom found in clear water or that containing only sphagnum moss. They must be sought in ponds rich in decaying vegetable matter, and nothing was more marked in Labrador where such ponds are non-existent than the scarcity of Hydrophilidæ. Since they too fly freely, for example the great *Hydrous triangularis* is often found beneath electric lights, data drawn from occasional occurrence of imagos must be used with caution. Notwithstanding this power of flight and the consequent wide distribution of the species, the study we made last winter of the local collection resulted in Mr. Wintersteiner's discovery that the supposed *Philhydrus cinctus* of the sandy regions of New Jersey was the more southern *P. consors*, affording an instance of the restriction of a distribution of a species by climatic conditions. As Mr. Sherman is to speak of the Dytiscidæ and Mr. Wintersteiner of the Hydrophilidæ, I will continue myself with mentioning one more case of the distribution of water beetles being controlled by environment. *Hydrobius tesselatus* is regarded by collectors as exceedingly rare, but wherever a long dead log can be found submerged in slowly moving fresh water, these beetles may be found clinging to the under surface; so Dr. Van Dyke and I found it at Lakehurst, where a rough bridge had been made by throwing logs down side by side across the stream, and Mr. Brownell has told me of a similar experience at Westwood, N. J., where numbers of this species were taken.

In studying Elmidæ we must resort to entirely new efforts in collecting, for they are so securely attached by their powerful claws to submerged stones, sticks and roots that ordinary methods rarely show results. At Yaphank Mr. Davis, Mr. Engelhardt and I waded into the shallow river and carried to the shore pieces of board, branches, etc., that we found in the water, and allowed them to dry out in the sun. On Staten Island and at Ramsey the same plan has been tried, always with the same result, these long-legged beetles commence to crawl away from the unwelcome light and heat and are then easily detected. But in the water or out of it while the stick is wet, they are liable to hide in crevices and defy detection. There used to be a tradition that only swiftly flowing streams contained such beetles, but Mr. Roberts long ago disproved it by finding them in great numbers on the submerged roots of willow trees, growing close to river banks, so that the roots protruded from the soil into

the water. Dr. Lutz has also taken them in numbers by roughly brushing the banks and bottoms of brooks, catching the loosened mud and insects in a piece of cheesecloth stretched across the brook lower down. It is evident that what the Elmidæ require is aerated water, and their formerly supposed dependence upon swiftly flowing streams only results from such being always well supplied with air. The occurrence of *Psephenus lecontei* at Niagara and other waterfalls is simply an extreme instance of this necessity for aerated water.

The difficulty attached to collecting the Elmidæ and perhaps the scarcity of suitable waters near New York have prevented us from doing a great deal with them, even the taxonomy is in a very unsettled condition; some of our local species including possibly one of those found in the Carman River at Yaphank, being still unnamed. The occurrence of some species will undoubtedly be found to depend upon the existence of certain conditions required for their welfare, and it is evident that we have in *Macronychus glabratus* a species that can accommodate itself to the slower moving streams, and is therefore relatively common at least on Staten Island, but we know too little about the other species to venture any comment at present.[1]

Of the other smaller groups of beetles aquatic in some stage, we know still less. We have no Georyssidæ in this vicinity, nor any Hydroscaphidæ. The Dascyllidæ are said to have aquatic larvæ, but no local collector has ever followed the matter up.

COLEOPTERA OF AQUATIC PLANTS.

In the preceding paragraphs we have been principally occupied with insects that frequent aquatic environments primarily for the sake of the water and what it contains, and we have noted in how many respects, in locomotion, in respiration, in vestiture and form they are modified to fit them for aquatic existence. Further, we have been able to discern how for each a special environment suited to its individual needs, is more or less essential to its existence. But in no instance has this environment so far involved special relations with a particular species of the plant world. There are, however, very many beetles living upon aquatic plants, modified to fit them for

[1] A curious statement in reference to Elmidæ is found in E. A. Butler's "Pond Life" to the effect that they occur in great numbers in the Cordilleras and are worked up with dough into lumps and sold under the name of "Chiche," the dish prepared from them being called "Chupe de chiche."

aquatic or semi-aquatic life. Of such the most completely aquatic in habit are found among the snout beetles. *Tanysphyrus lemnæ,* living on *Lemna* and perforating its leaves, *Amalus myriophylli,* on *Myriophyllum, Phytobius velatus,* on *Potamogeton,* and *Stenopelmus rufinasus* on *Azolla,* are nearly all known in both the old world and the new, living indifferently above or below the surface of the water, as adults, and within the tissues of the plants as larvæ. The adults cannot swim, but depend upon the current to float them from one plant to another, and are protected by hydrofuge pubescence for such voyages or for the times when oviposition requires their descending below the surface. Their adaptation to an aquatic existence ends there, and the controlling factor in their environment is really the relation to the food plant. In the case of the larvæ there is even less modification, for as it derives its supply of air from the tissues of the plant on which it feeds, there is no need of special respiratory apparatus. In a very qualified way therefore we may include all beetles feeding upon aquatic or palustral plants, principally because in the adults we shall always be able to note some adaptive modification of vestiture. Such beetles will include the species of the genus *Donacia,* which feed on water lilies, pickerel weed, *Sagittaria,* and various other aquatic plants and sedges, the name itself being derived from *Donax,* a reed. In the case of those feeding on water lilies the larvæ feed on the rootlets three or four feet below the surface of the water, being provided with sharp anal appendages for the better piercing of the air cells in the plant (not on the stems as has been stated). I have found on roots dragged out of the mud at the bottom, leathery cocoons, which in winter contain larvæ and in early spring pupæ, from which the adults have later hatched. McGillivray has given excellent details and figures of these insects. Although the adults remain above the surface of the water and deposit their eggs on leaves at the surface, the other stages are thus spent below the surface. The allied genus *Hæmonia* is even more aquatic than *Donacia,* it lives on *Potamogeton,* goes below the surface to oviposit and has proved capable in captivity of living submerged for many weeks. Brocher has experimented with the European species which is provided with the peculiar pubescence described above, as capable of maintaining a thin sheet of air about the body, thus permitting the insect to remain long below the surface instead of resting on aquatic foliage like

Donacia. A considerable number of snout beetles besides those already mentioned attack aquatic plants and should be included. *Listronotus latiusculus* was found by Dr. C. M. Weed in all its stages in the stems of *Sagittaria variabilis; L. appendiculatus* by Mr. W. Jülich, in the stems of reeds; *Macrops solutus* and *sparsus* also breed in the stalks of *Sagittaria*. Some species of Lixus have been bred from stems of *Polygonum amphibium* by Popenoe, *Lissorhoptrus* lives on the roots of rice, and the various species of *Sphenophorus* also infest the roots or lower parts of the stems of graminaceous plants, including those that grow in wet places. These Rhynchophora are here included because their surface indicates an adaptation to aquatic conditions, being clothed in every instance with hydrofuge pubescence or with imbricated scales. These are but a few instances of beetles dependent upon plants growing in water. Many others could doubtless be cited by those collectors who have specially studied ponds and swamps, and much remains to be learned in regard to the food plants of our local palustral Coleoptera.

SPECIAL QUESTIONS.

As to salt or brackish water, I think it may be said that at best it is tolerated by beetles. *Philhydrus hamiltoni* seems to be a denizen of salt marshes exclusively, but all the genera and most of the species of Hydrophilidæ found there would also be found elsewhere and in greater numbers. In other families I know of no salt water species. The difference between stagnant and moving water is on the contrary very marked in its influence. The Parnidæ and Elmidæ, which are comparatively stationary, must depend upon the current bringing them air, hence practically none are found in still water. Most of the Hydrophilidæ feed upon decaying vegetation, and would be ruined where a swift current kept the bottom clean, hence the members of this family are seldom found in moving water; but there are all degrees of motion, and between a stagnant ditch and a slowly moving swamp the difference in respect of motion is not great, and leads up so gradually to the slowly moving streams of flat plains that one is not surprised to find Parnidæ and Elmidæ in sphagnum bogs or *Hydrobius* beneath submerged bridge logs. As I have before pointed out a moderate degree of flexibility in habits will tend to broaden the distribution of a species, while the converse would go far towards entering it in the

class of rare or local species, and there is a great difference between species in respect of flexibility, as I have shown in treating the distribution of *Cicindela.*

The influence of light and shade appears to be marked in the case of *Agabetes acuductus,* found only in woodland pools, but in general the amount of light which penetrates the water must be so reduced that its further diminution by the shade of trees cannot be of great importance.

The Gyrinidæ circling about the surface of the water in broad daylight shun the light less than most aquatic beetles, which will usually be found during the day among the mosses and leaves or hiding in the banks.

Temporary pools afford little in beetle life, and were it not for the beetle's nocturnal errors, would perhaps contain nothing. As a rule the presence of vegetable or animal matter, food of some sort, is a positive requirement for successful water beetle fishing. Given food even the lowest temperatures seem of little consequence; I have seen water beetles swimming beneath transparant ice thick enough to bear my weight, and Mr. Engelhardt can bear witness to the numbers that we found in the bitter cold pools of Labrador. No beetles were there more numerous than the water beetles.

In conclusion it seems to me that while the environment may be somewhat varied for many species that are capable of adapting themselves to varied conditions, the species that might perhaps be called the common species, the environment for others, the so-called rare species, must be exactly right or they cannot maintain their existence. And even for such, an element of accident also comes into play, for such beetles are often missing where the environment is found. Every lily pad does not support a *Donacia.* In traveling to Staten Island once via New Jersey trolley road, I was told that the trolley car connected with a boat for Staten Island. Arriving at the terminus, no boat was in sight, nor did one appear for a long time, so the environment being right and the boat missing I questioned the dock man, and learned that there was "a car agin every boat but not a boat agin every car." So the student of environment must not be discouraged by apparent failure to connect the beetle with the environment, but remember that there is not always a "boat agin every car."